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Nitrite levels in Well water from different Rural areas in Morocco

Youssef El Baroudi[1], Chadia Ouazzani[1]*, Azzedine Er-Ramly[2], Abdellah Moustaghfir[2], Issam Essebbahi[1], Abdallah Dami[1] and Lhoussine Balouch[1]

[1]Laboratory of Biochemistry and Molecular Biology, Faculty of Medicine and Pharmacy, Mohammed V University of Rabat, Morocco
[2]Laboratoty of Research Odontological, Biomaterials and Nanotechnology, Faculty of Dentistry, Mohammed V University of Rabat, Morocco

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ABSTRACT

Nitrites are an intermediate product involved in the oxidation and reduction reactions of the nitrogen cycle. They are considered toxic and are only found in minimal concentrations in well water. Agricultural (manure, use of nitrogen fertilizers...) and industrial activities, discharges from wastewater treatment plants, urban waste and human and animal excreta are the main parameters that lead to the increase in concentration and contamination by nitrites in well waters. The objective of this study was to determine and evaluate the level of contamination of well water in different rural areas in Morocco and to show the potential impact of this contamination on the health of the population. This is a prospective study carried out on 53 samples collected in 10 rural areas in Morocco. The physico-chemical analyses showed that out of the 53 samples, 25 exceeded the Moroccan standards (N.M. 03.7.001) of 0.1 mg/l at the exitof water treatment facilities and 9 samples exceeded the international standards of 0.2 mg/l set by the WHO. The consumption of this water contaminated by nitrites can have, in the long term, a harmful effect on health and mainly by the appearance of methemoglobinemia. These results show the seriousness of the problem and the need to implement concrete sanitary measures to correct it in order to ensure the protection of the health of the population living in rural areas.

Key words : *Nitrite, Well water, Rural area, Morocco.*

Introduction

As part of the nitrogen cycle, nitrate and nitrite ions are naturally present in the environment (soil, water...). Nitrates (NO_3^-) represent the most stable oxidation state and are important nutrients for plants. They are often present in low concentrations in water with a limit value for human consumption of 50mg/l (WHO, 1998; NM 03.7.001, 2006).

Nitrite (NO_2^-) is the most toxic element of the nitrogen cycle. They are present in water in minimal concentration with a limit value for human consumption of 0.2 mg/l according to the WHO (WHO, 1998) and 0.1 mg/l at the exit of water treatment facilities according to the Moroccan standard of 2006 on the quality of water for human consumption (NM 03.7.001, 2006).

The problem of contamination of ground and surface waters by nitrates and nitrites is frequently encountered and is mainly related to human activity: agricultural activity (manure, use of nitrogenous fertilizers...), industrial activity, discharges from wastewater treatment plants, urban waste and human and animal excreta. The increase of nitrite con-

centration in water is mainly due to the reduction of nitrates in reducing medium or by action of bacteria of the genus "Nitrosomonas". This is related to the stagnation of low oxygenated drinking water in galvanized steel distribution pipes or to the use of chlorination to maintain a residual concentration of disinfectant. It can also result from excess ammonia (NH_3) entering the distribution system potentially leading to nitrification (oxidation of NH_3 to NO_2^- and then NO_3^-). In vivo, nitrite can be formed by reduction of ingested nitrate (WHO, 2017).

High levels of nitrite in drinking water have repercussions on the appearance of several pathologies: cancer (FAO/WHO, 2003; RIVM, 1989) by the transformation of nitrite into nitrosamines in the stomach, insulin-dependent diabetes mellitus (type 1 diabetes) (Kostraba *et al.*, 1992; Parslow *et al.*, 1997) and an abnormality of the thyroid gland (goiter) (Höring, 1992). Its main toxicity lies in the transformation of hemoglobin into methemoglobin by oxidation of ferrous iron (Fe^{2+}) into ferric iron (Fe^{3+}) making oxygen transfer impossible. Methemoglobinemia, defined as the formation of elevated levels of methemoglobin greater than 10%, is manifested by clinical symptoms ranging from cyanosis to asphyxia in the most severe cases. Infants are the most likely to develop complications due to methemoglobinemia (blue baby syndrome) (WHO, 2017).

The objective of this study is to evaluate the nitrite content of well water in 10 rural areas in Morocco and to determine the potential risks of intoxication of the population by the consumption of this water.

Materials and Methods

Materials

A total of 53 well water samples were collected between the period of September 2020 and February 2021 in 10 rural areas in Morocco (Figure 1): Sidi Slimane - Sidi Kacem (Table 1), Had Soualem - Settat (Table 2), Kenitra (Table 3), Larache-Tanger (Table 4), Skhirat-Harhoura (Table 5), Fez (Table 6), Tit Mellil (Table 7), Khouribga (Table 8), Brachoua (Table 9), Tiflet (Table 10). The samples taken were placed in polyethylene bottles and stored at a temperature of 4°C. The analyses were carried out on the same day of the sampling.

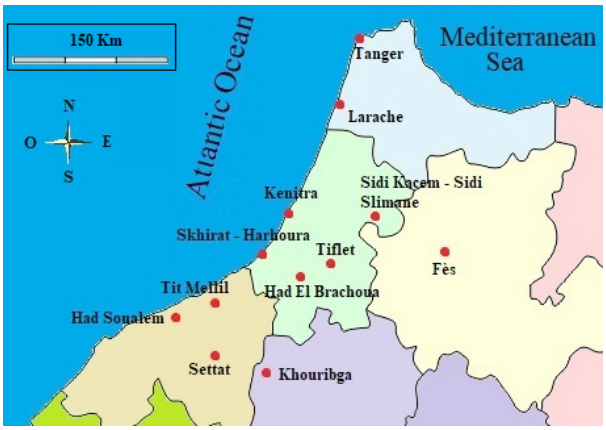

Fig. 1. Distribution of sampling stations

Table 1. Geographical data of well water samples from the region of Sidi Slimane - Sidi Kacem

Samples	Location	Coordinates
P1	Sidi Slimane	34°152353 nord, 5°552453 ouest
P2	Sidi Slimane	34°152353 nord, 5°552453 ouest
P3	Jamaât Zirara – Sidi Kacem	34°132003 nord, 5°422003 ouest
P4	Jamaât Zirara – Sidi Kacem	34°152353 nord, 5°552453 ouest
P5	Sidi Kacem	34°132003 nord, 5°422003 ouest

Table 2. Geographical data of well water samples from the Had soualem – Settat region

Samples	Location	Coordinates
P6	Had Soualem	33°252043 nord, 7°502503 ouest
P7	Had Soualem	33°252043 nord, 7°502503 ouest
P8	Settat	33°002003 nord, 7°372003 ouest

Table 3. Geographical data of well water samples from the Kenitra region

Samples	Location	Coordinates
P9	Kenitra	34°152003 nord, 6°352003 oust
P10	Kenitra	34°152003 nord, 6°352003 oust
P11	Kenitra	34°152003 nord, 6°352003 oust
P12	Kenitra	34°152003 nord, 6°352003 oust
P13	Kenitra	34°152003 nord, 6°352003 oust

Table 4. Geographical data of well water samples from the Larache - Tangier region

Samples	Location	Coordinates
P14	Larache	35°112003 nord, 6°092003 ouest
P15	Larache	35°112003 nord, 6°092003 ouest
P16	Larache	35°112003 nord, 6°092003 ouest
P17	Larache	35°112003 nord, 6°092003 ouest
P18	Larache	35°112003 nord, 6°092003 ouest
P19	Tanger	35°462013 nord, 5°482003 ouest
P20	Tanger	35°462013 nord, 5°482003 ouest

Table 5. Geographical data of well water samples from the region of Skhirat – Harhoura

Samples	Location	Coordinates
P21	Oulad Hbri – Skhirat	33°512133 nord, 7°022083 ouest
P22	Oulad Hbri – Skhirat	33°512133 nord, 7°022083 ouest
P23	Kbayl Sbah – Oulad Msoun Rkhoukha – Skhirat	33°512133 nord, 7°022083 ouest
P24	Kbayl Sbah – Oulad Msoun Rkhoukha – Skhirat	33°512133 nord, 7°022083 ouest
P25	Harhoura	33°572003 nord, 6°552483 ouest

Table 6. Geographical data of well water samples from the Fez region

Samples	Location	Coordinates
P26	Fès	34°032003nord, 4°582593 ouest
P27	Fès	34°032003nord, 4°582593 ouest
P28	Fès	34°032003nord, 4°582593 ouest
P29	Fès	34°032003nord, 4°582593 ouest
P30	Taâounyat Brida – Batmat Bjlafa- Ain Lah – Fès	34°032003nord, 4°582593 ouest
P31	Taâounyat Al Farah – Ain Lah – Fès	34°032003nord, 4°582593 ouest
P32	Taâounyat Ghalia – Ain Lah – Fès	34°032003nord, 4°582593 oust

Table 7. Geographic data of well water samples from the Tit Mellil region

Samples	Location	Coordinates
P33	Tit Mellil	33°332293 nord, 7°292093 oust
P34	Tit Mellil	33°332293 nord, 7°292093 oust

Table 8. Geographical data of well water samples from the Khouribga region

Samples	Location	Coordinates
P35	Khouribga	32°532003 nord, 6°542003 oust
P36	Khouribga	32°532003 nord, 6°542003 oust
P37	Khouribga	32°532003 nord, 6°542003 oust
P38	Khouribga	32°532003 nord, 6°542003 oust
P39	Khouribga	32°532003 nord, 6°542003 oust
P40	Khouribga	32°532003 nord, 6°542003 oust
P41	Khouribga	32°532003 nord, 6°542003 oust
P42	Khouribga	32°532003 nord, 6°542003 oust
P43	Khouribga	32°532003 nord, 6°542003 oust
P44	Khouribga	32°532003 nord, 6°542003 ouest
P45	Khouribga	32°532003 nord, 6°542003 ouest

Table 9. Geographic data of well water samples from the Brachoua region

Samples	Location	Coordinates
P46	Enkhila – Brachoua	33°412393 nord, 6°372533 ouest
P47	Enkhila – Brachoua	33°412393 nord, 6°372533 ouest
P48	Enkhila – Brachoua	33°412393 nord, 6°372533 ouest
P49	Enkhila – Brachoua	33°412393 nord, 6°372533 ouest
P50	Enkhila – Brachoua	33°412393 nord, 6°372533 ouest
P51	Enkhila – Brachoua	33°412393 nord, 6°372533 ouest

Table 10. Geographic data for well water samples from the Tiflet region

Samples	Location	Coordinates
P52	Tiflet	33°532353 nord, 6°182253 ouest
P53	Tiflet	33°532353 nord, 6°182253 ouest

Method

Determination of nitrites

Nitrite (NO_2^-) levels in well water samples (in duplicate tests) are determined by the colorimetric method of Griess (Fox, 1979). In an acidic medium, a diazotization reaction of an aromatic primary amine: sulfanilamide by NO_2^- present in the water and formation of a diazonium salt. In the presence of N-(1-Naphthyl) ethylenediamine (NED), a coupling reaction occurs leading to the formation of a pink colored complex allowing a colorimetric determination by spectrometry at a wavelength of 540 nm. The absorbance of the samples is subtracted from that of a control in which the well water is replaced by distilled water. The nitrite concentration of the samples is determined by comparison to the calibration curve ranging from 0.02 mg/l to 0.2 mg/l.

Results

Variation of pH and nitrite level in well water

The pH values in the well water in the Sidi Kacem - Sidi Slimane regions vary between 7.50 and 8.86 (Table 11).

The nitrite levels found in the well water are 0.1 mg/l, 0.2 mg/l, 0.49 mg/l, 0.14 mg/l and 0.1 mg/l respectively in the Sidi Slimane and Sidi Kacem regions (Figure 2).

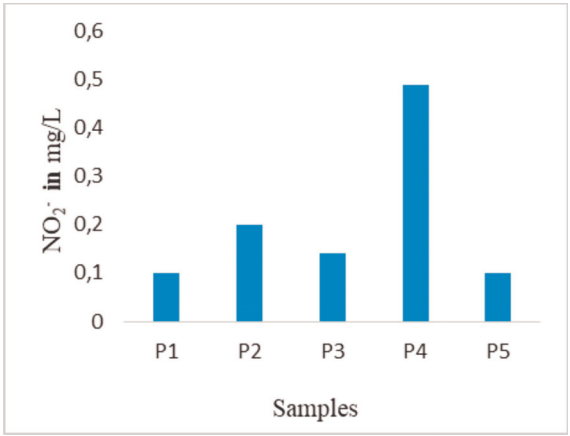

Fig. 2. Nitrite content in mg/l in well waterintheregions of Sidi Slimane - Sidi Kacem

Table 11. Variation of pH in well water in the regions of Sidi slimane - Sidi Kacem

Samples	P1	P2	P3	P4	P5
pH	8.86	7.91	7.90	7.70	7.50

The pH values in well water in the Had Soualem - Settat regions vary between 7.40 and 7.9 (Table 12).

The nitrite levels found in the well water are 0.40 mg/l, 0.66 mg/l and 0.1 mg/l respectively in the Had Soualem and Settat regions (Figure 3).

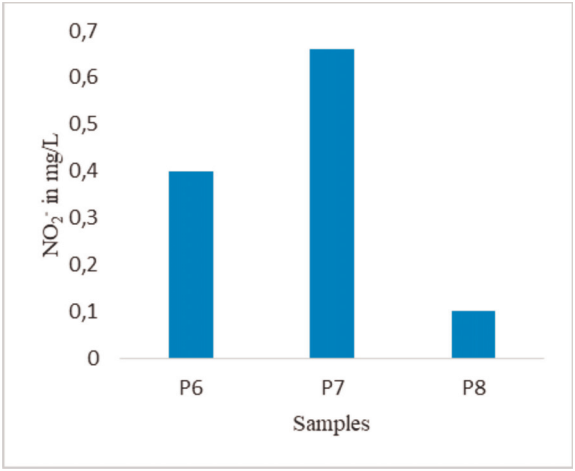

Fig. 3. Nitrite content in mg/l in well water from the Had Soualem - Settat regions

Table 12. Variation of pH in well water in the regions of Had Soualem – Settat

Samples	P6	P7	P8
pH	7.40	7.9	7.69

The pH values in the well water in the Kenitra region vary between 7.05 and 8.8 (Table 13).

The nitrite levels found in the well water are 0.06 mg/l, 0.16 mg/l, 0.21 mg/l, 0.49 mg/l and 2.3 mg/l in the Kenitra region (Figure 4).

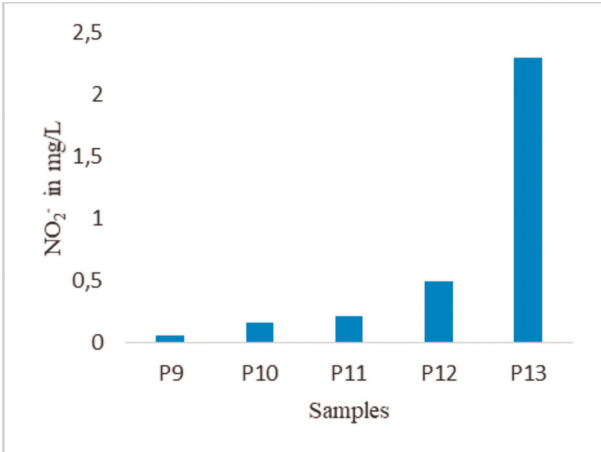

Fig. 4. Nitrite content in mg/l in well water in the Kenitra region

Table 13. Variation of pH in well water in the Kenitra region

Samples	P9	P10	P11	P12	P13
pH	7.65	7.8	8.8	7.05	7.6

The pH values in the well water in the Larache - Tangier regions vary between 7.40 and 8.12 (Table 14).

The nitrite levels found in the well water are 0.086 mg/l, 0.026 mg/l, 0.17 mg/l, 0.086 mg/l, 0.013 mg/l, 0.03 mg/l and 0.05 mg/l respectively in the Larache and Tangier regions (Figure 5).

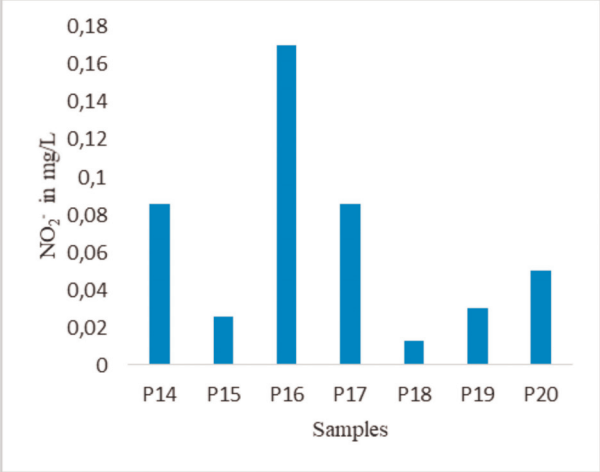

Fig. 5. Nitrite content in mg/l in well water in the Larache - Tangier regions

Table 14. Variation of pH in well water in the Larache - Tangier regions

Samples	P14	P15	P16	P17	P18	P19	P20
pH	7.72	8.12	7.60	7.55	7.58	7.40	7.56

The pH values in the well water in the Skhirat - Harhoura regions vary between 7.22 and 8 (Table 15).

Nitrite levels in well water are 0.13 mg/l, 0.14 mg/l, 0.065 mg/l, 0.08 mg/l and 0.04 mg/l respectively in Skhirat and Harhoura regions (Figure 6).

Table 15. Variation of pH in well water in the regions of Skhirat – Harhoura

Samples	P21	P22	P23	P24	P25
pH	8	7.85	7.4	7.22	7.6

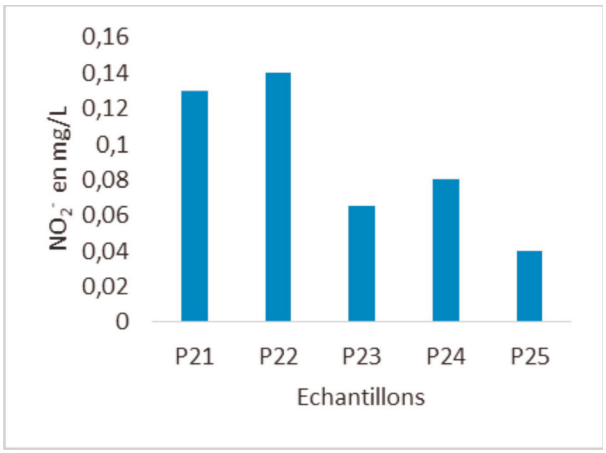

Fig. 6. Nitrite content in mg/l in well water in the Skhirat - Harhoura regions

The pH values in the well water in the Fez region vary between 7.06 and 7.6 (Table 16).

The nitrite levels found in the well water are 0.15 mg/l, 0.65 mg/l, 0.53 mg/l, 0.072 mg/l, 0.073 mg/l, 0.06 mg/l and 0.01 mg/l in the Fez region (Figure 7).

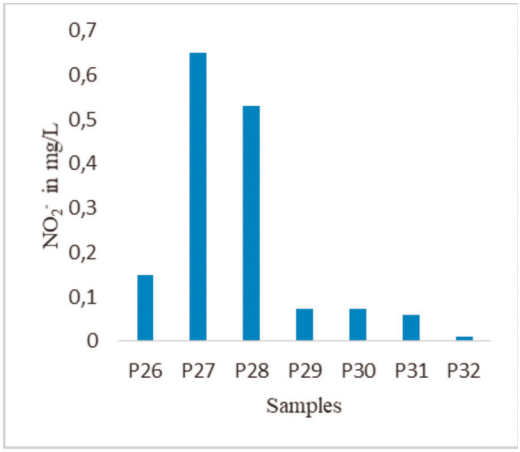

Fig. 7. Nitrite content in mg/l in well water from the Fez region

Table 16. Variation of pH in well water in the Fez region

Samples	P26	P27	P28	P29	P30	P31	P32
pH	7.43	7.06	7.53	7.47	7.6	7.57	7.52

The pH values in the well water in the Tit Mellil area vary between 6.87 and 6.98 (Table 17).

Nitrite levels in the well water are 0.15 mg/l and 0.04 mg/l in the Tit Mellil area (Figure 8).

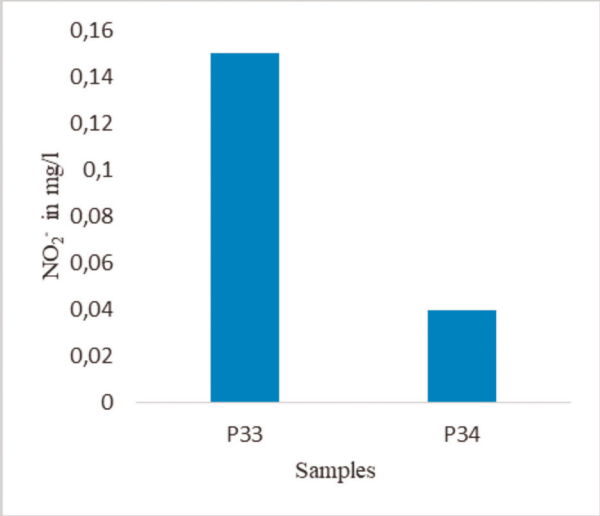

Fig. 8. Nitrite content in mg/l in well water in the Tit Mellil region

Table 17. Variation of pH in well water in the Tit Mellil region

Samples	P33	P34
pH	6.98	6.87

The pH values in the well water in the Khouribga region vary between 8 and 8.9 (Table 18).

The nitrite levels found in the well water are 0.03 mg/l, 0.11 mg/l, 0.09 mg/l, 0.003 mg/l, 0.17 mg/l, 0.04 mg/l, 1.66 mg/l, 0.24 mg/l, 0.06 mg/l, 0.02 mg/l and 0.04 mg/l in the Khouribga region (Fig. 9).

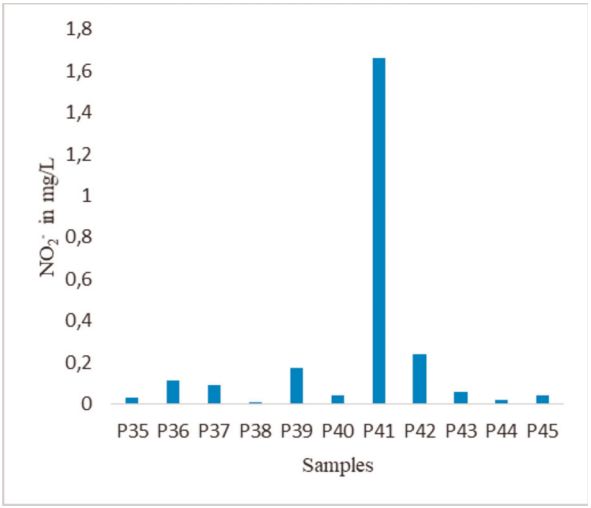

Fig. 9. Nitrite content in mg/l in well water in the Khouribga region

Table 18. Variation of pH in well water in the Khouribga region

Samples	P35	P36	P37	P38	P39	P40
pH	8.8	8.9	8.8	8.5	8.9	8.5
Samples	P41	P42	P43	P44	P45	
pH	8.9	8	8.16	8.4	8.27	

The pH values in the well water in the Brachoua area range from 7.13 to 7.75 (Table 19).

Nitrite levels in well water were 0.1 mg/l, 0.11 mg/l, 0.11 mg/l, 0.16 mg/l, 0.15 mg/l and 0.072 mg/l in the Brachoua area (Figure 10).

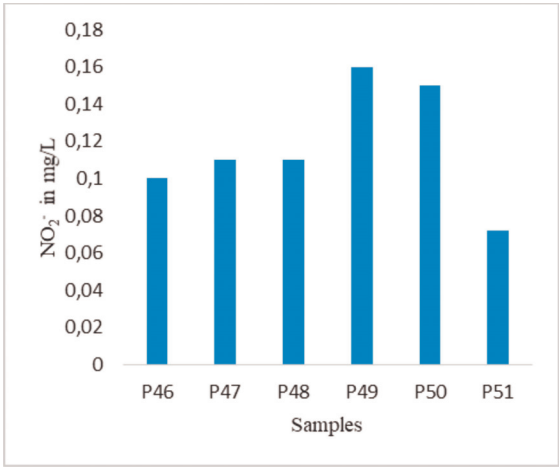

Fig. 10. Nitrite content in mg/l in well water from the Brachoua region

Table 19. Variation of pH in well water in the Brachoua region

Samples	P46	P47	P48	P49	P50	P51
pH	7.51	7.36	7.20	7.13	7.75	7.67

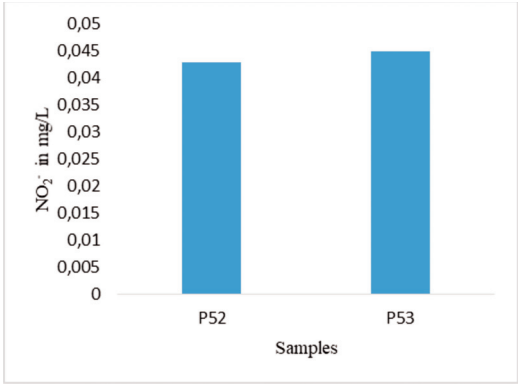

Fig. 11. Nitrite content in mg/l in well water from the Tiflet region

Table 20. Variation of pH in well water from the Tiflet region

Samples	P52	P53
pH	7.64	7.75

The pH values in well water in the Tiflet area range from 7.64 to 7.75 (Table 20).

Nitrite levels in the well water are 0.043 mg/l and 0.045 mg/l in the Tiflet region (Figure 11).

The highest nitrite levels were observed in the region of Kenitra, followed by Khouribga, Had Soualem - Settat, Fez and Sidi Slimane - Sidi Kacem. The regions of Larache - Tangier, Tit Mellil, Skhirat - Harhoura, Tiflet and Brachoua had nitrite levels ranging from 0.026 mg/l to 0.17 mg/l (Figure 12).

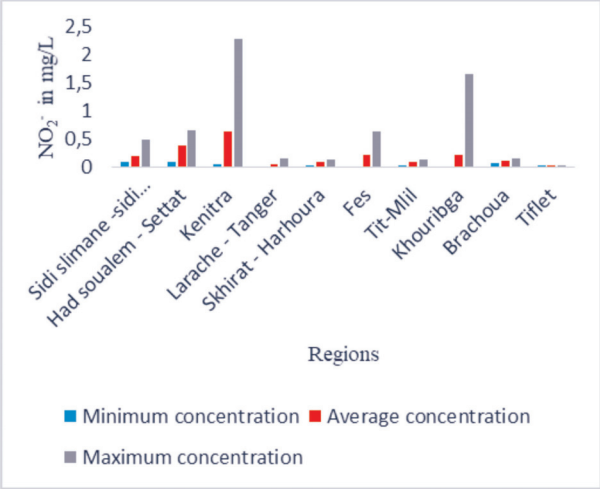

Fig. 12. Min - Average - Max nitrite concentrations by region in mg/l

Discussion

The pH depends on several parameters including environmental factors, temperature, dissolved CO_2 and O_2, fauna, lighting, nature of the terrain(Azami Hassani T, 1996), respiration of organisms, salinity, origin of the water, active assimilation of carbon dioxide with chlorophyll (chlorophyll assimilation) and metabolism of bacteria and fungi (Louah, 1995).

The pH values of 46 samples of the studied well waters vary between 6.87 and 8.9 meeting the Moroccan standard NM 03.7.001 (6.5 and 8.5)(NM 03.7.001, 2006). Wells P1, P11, P35, P36, P37, P39 and P41 have a pH (between 8.8 and 8.9) higher than the Moroccan standard. The nature of the soil or the agricultural activity (use of phytosanitary products, manure...) could be the cause of these high pH values.

High nitrite levels in well water are related to human activities, mainly industrial and agricultural activities with the use of nitrogenous fertilizers and plant protection products that subsequently seep through the soil to the water table, point and dispersed discharges of livestock products, manure use, discharges from sewage treatment plants(EL Asslouj *et al.*, 2007; Lyakhloufi *et al.*, 1999; HAKKOU R, 2001), urban waste and human and animal excreta. The increase in nitrite concentration may also be due to the reduction of nitrate by bacterial action.

The nitrite contents of the 53 well water samples analyzed show that 9 water samples exceed the international standards of 0.2 mg/l set by the WHO and 25 exceed the Moroccan standards (N.M. 03.7.001) which sets the limit of nitrite concentration in water for human consumption at 0.1 mg/l at the exit of the treatment facilities. In the case of our study, almost all the contaminated wells had as source of pollution agricultural activity and in particular the use of pesticides and manure, except for the samples P7 of the region of Had Soualem, the sample P13 of the region of Kenitra and the sample P41 of the region of Khouribga which were in the vicinity of industry and can, consequently, have been contaminated by the industrial activity. These 3 samples affected by industrial activity had a higher level of contamination than the wells contaminated by agricultural activity with nitrite concentrations of 0.66 mg/l, 2.3 mg/l and 1.66 mg/l respectively in the Had Soualem, Kenitra and Khouribga regions. The consumption of water from contaminated wells can, in the long term, have a detrimental effect on the health of the population and in particular in the appearance of methaemoglobinaemia (Kostraba *et al.*, 1992; Idrissi L, 2006)which results in the transformation of haemoglobin into methaemoglobin following the oxidation of ferrous iron (Fe^{2+}) into ferric iron (Fe^{3+}) making it impossible for oxygen to be transferred in the body. This can affect infants under 3 months of age(Phaneuf D, 2004). Indeed, infants, pregnant and lactating women are the most likely to be affected by the pathology.

Other studies carried out in the regions of Chaouia (Mzamza Community)(EL Asslouj J, 2007), Settat(Hassoune E, 2006) and Martil(Lamribah A, 2013) join our results and also show a contamina-

tion of well water by nitrites. However, studies conducted in the regions of Kenitra (Maâmoura)(Daifi, 2014; Kherrati, 2014), Meknes (Ain Salama-Jerri)(Ghazali D, 2013), Fez (Haissoufi *et al.*, 2011; Ouedghiri *et al.*, 2014), the city of Tijikja (Mauritania)(Ould Cheikh *et al.*, 2011) and the city of Nouakchott (Mauritania)(Ould Dick, 2017) showed that water intended for human consumption in these regions had nitrite levels in accordance with international standards and was therefore not affected by contamination.

Conclusion

The physico-chemical analyses carried out in this study allowed to determine the nitrite concentrations of well waters from 10 regions in Morocco: Sidi Slimane - Sidi Kacem, Had Soualem - Settat, Kenitra, Larache-Tanger, Skhirat-Harhoura, Fez, Tit Mellil, Khouribga, Brachoua, Tiflet. The results of the analyses revealed that out of 53 samples, 9 water samples exceeded the international standards of 0.2 mg/l set by the WHO and 25 exceeded the Moroccan standards (N.M. 03.7.001) of 0.1 mg/l at the exit of the water treatment facilities. These polluted waters consumed by the population present toxicity risks and can have, in the long term, harmful effects on health. The pollution of the well water studied in this work can be caused by agricultural intensification accompanied by the use of phytosanitary products, manure and nitrogenous fertilizersas well as by industrial activity, wastewater treatment plant discharges and urban waste and human and animal excreta.

These results show the seriousness of the problem and the need to take concrete sanitary measures in order to limit and correct the pollution that affects the water intended for human consumption and protect, therefore, the health of the population living in rural areas. Therefore, measures and recommendations are proposed to correct this situation, such as:

- Treatment of water for human consumption;
- Continuous monitoring of well water quality;
- Prohibit the discharge of wastewater near wells;
- Ensure access to drinking water for the population living in rural areas;
- Controlling the use of phytosanitary products and nitrogenous fertilizers;
  Monitoring the health of the population;
- Carrying out awareness campaigns among the population living in rural areas and consuming well water.

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